

## Experienced poker players differ from inexperienced poker players in estimation bias and decision bias

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### Abstract

This paper investigates the similarity or difference in cognitive bias on a poker task between experienced poker players (EPPs) and inexperienced poker players (IPPs). EPPs were compared with IPPs on probability estimation (estimation bias) and choice (decision bias). It was hypothesized that EPPs would have lower estimation bias and lower decision bias compared with IPPs, and that a player's level of experience could be identified from gambling behavior. Results indicate that EPPs significantly overestimated accepted gambles, but had significantly smaller estimation bias and decision bias compared with IPPs. All players could accurately be classified as "experienced" or "inexperienced" based on their estimation bias and decision bias. It is concluded that EPPs have significantly lower estimation bias and decision bias than do IPPs on the poker task presented in this research study. Despite significantly higher overestimation, EPPs make better decisions than IPPs. These findings are posited to have implications for the study of cognitive bias in pathological gambling and addiction.

**Keywords:** poker, cognitive bias, Texas Hold'em

### Introduction

Poker has gained tremendous popularity in recent years, as evidenced by widely popular Internet poker Web sites and televised poker tournaments. As popularity and availability for playing poker increase, so does the risk for some individuals to develop problem or pathological gambling. Pathological gambling is characterized by maladaptive gambling behavior (American Psychological Association, *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition [DSM-IV], 1994), in which the individual continues gambling despite negative consequences such as incurred losses or jeopardized social relations. Cognitive biases, that is, distorted perceptions of probability and outcome, play a central role in problem gambling and are manifested in diverse ways,

including overestimation or overconfidence of winning, selective attention toward gains, erroneous perceptions, superstitions, rituals, and illusion of control (Delfabbro, 2004; Delfabbro & Winefield, 2000; Floyd, Whelan, & Meyers, 2006; Goodie, 2003, 2005; Ladouceur, 2004a; Ladouceur, Tourigny, & Mayrand, 1986; Lakey, Goodie, & Campbell, 2006; Lakey, Goodie, Lance, Stinchfield, & Winters, 2007; Linnet, Rojskjaer, Nygaard, & Maher, 2006; Raylu & Oei, 2002; Toneatto, Blitz-Miller, Calderwood, Dragonetti, & Tsanos, 1997).

Cognitive biases influence most forms of decision making, and the context of decision making can influence these biases. For instance, Kahneman and Tversky (1979, 1984) showed that people are often loss averse when faced with the possibility of losing a gain. These researchers found that most individuals prefer a certain gain of \$800 rather than an 85% chance of gaining \$1,000, even though the latter choice is more profitable in the long run. They also showed that people often are more willing to take risks when faced with the uncertain possibility of incurring a loss; for example, most individuals prefer an 85% chance of losing \$1,000 rather than a certain loss of \$800, even though the former choice leads to more losses in the long run. The question of cognitive bias is therefore one of *degree* — not presence or absence — as everyone holds cognitive biases to a certain extent. In relation to gambling, particularly skill games such as poker, the central question of cognitive bias is whether the degree of cognitive bias differs among gamblers, for instance, between experienced and inexperienced gamblers or between experienced and pathological gamblers.

Cognitive biases are involved in all forms of gambling and are associated with different gambling activities, including lotteries, slot machines, sports betting, racetrack betting, and casino games (Benhsain, Taillefer, & Ladouceur, 2004; Brownstein, Read, & Simon, 2004; Cantinotti, Ladouceur, & Jacques, 2004; Caron & Ladouceur, 2003; Cote, Caron, Aubert, Desrochers, & Ladouceur, 2003; Delfabbro, 2004; Delfabbro, Lahn, & Grabosky, 2006; Delfabbro & Winefield, 2000; Gibson & Sanbonmatsu, 2004; Gilovich, 1983; Gilovich & Douglas, 1986; Joukhador, Blaszczynski, & Maccallum, 2004; Joukhador, Maccallum, & Blaszczynski, 2003; Ladouceur, 2004b; Ladouceur, Tourigny, & Mayrand, 1986; Larsen, McGraw, Mellers, & Cacioppo, 2004; Rogers, 1998; Rogers & Webley, 2001). Biases are not specific to problem or pathological gambling, but are crucial in understanding how people are addicted to gambling and how the disorder can be treated. For instance, treatment of *erroneous perceptions*, a subset of cognitive biases, is an efficient treatment for pathological gambling (Ladouceur et al., 2001, 2003; Ladouceur, Sylvain, Letarte, Giroux, & Jacques, 1998).

Cognitive biases influence decision making, resulting in increased risk willingness when winning probabilities are seen as high and in risk aversion when winning probabilities are seen as low. In a series of studies, Goodie and Lakey (Goodie, 2003, 2005; Lakey et al., 2006, 2007) found that problem and pathological gamblers were more confident in their decisions about a general knowledge task, even though they had no greater competence or performance level than non-gambling controls. Problem and pathological gamblers were also more likely to accept lower probability gambles, which suggests a higher degree of cognitive bias.

At present, very little is known about the role of cognitive bias in poker. Our long-term goal is therefore to develop a method to study bias in pathological gamblers. As a first step toward this goal, we developed a method to measure bias in gamblers. In the present study, we compared experienced poker players (EPPs) with novice poker players to determine whether the method could successfully differentiate novice and experienced players. If successful, the method could be applied to future studies of pathological gambling. We designed a poker task simulating an on-line gambling environment. In this task (described at length in the Materials and Method section), players estimated the winning probability of different hands and determined whether they would play the hand (i.e., accept the gamble) or not play the hand (i.e., reject the gamble). From this information, it was possible to determine the estimation bias (i.e., the difference between the estimated probability and the “real” probability of winning the hand), as well as the decision bias (i.e., the extent to which gamblers played high or low probability hands).

We hypothesized that EPPs would have lower estimation bias, smaller decision bias, and stronger association between estimation bias and decision bias compared with inexperienced poker players (IPPs). Specifically, we hypothesized that: (1) EPPs would have smaller estimation bias and decision bias than would inexperienced players; (2) EPPs would show a more differentiated estimation bias on accepted versus rejected gambles compared with IPPs; and (3) experienced and IPPs could be accurately classified on the basis of their estimation bias and decision bias.

## Materials and Methods

### Participants

Participants were recruited at Aarhus University, Denmark, through an internal advertisement at the Center of Functionally Integrative Neuroscience at Aarhus University. We defined EPPs as individuals who had prior extensive knowledge with playing poker (i.e., had played for at least 1 year) and who played on a regular basis (i.e., at least once a week) either on-line, in casinos, or in poker clubs. The preferred form of poker among participants was on-line poker. IPPs were defined as individuals who were familiar with the rules of poker, but otherwise had little or no experience with playing poker. These inexperienced players were comparable to poker beginners (i.e., individuals starting to learn poker). Participants volunteered their participation; they did not receive compensation for their time, and they did not wager money or otherwise risk losing money while participating in this study. No monetary incentives or risks were associated with participation. Investigators interviewed participants about their poker history and conducted a clinical assessment to ensure that there were no gambling problems, either past or present. Using the cohort selection criteria described below, we recruited five EPPs and four IPPs. All EPPs were male and all IPPs were female. In Denmark, the present data did not require formal approval from the Science Ethics Committee, because they only involved questionnaire-based ratings of probability and the decision to play or fold, and did not include human biological material (see also “Ethics approval” section that follows References).

### Poker task

As Figure 1 illustrates, we used a poker task simulating real-life Texas Hold'em poker (see e.g., Dennis, 2005), with a *flop* (i.e., three cards face up, which are common cards shared by all players), two *pocket cards* (i.e., two cards face up, which are visible to the player), and one opponent with two pocket cards face down. The player's objective is to determine the winning probability of the hand against the opponent and to determine whether to accept the gamble (i.e., play the hand) or reject the gamble (i.e., *fold* the hand). In real-life poker playing, the hand would involve wagering money (i.e., betting and/or raising), as well as revealing up to two more common cards (i.e., the *turn* and *river* cards). To reduce the number of variables, the poker task did not involve any of these additional features.

Participants were informed that they played against an optimal player, who could accurately determine the probability of winning and would play accordingly. Participants were instructed to accept or reject gambles to maximize the likelihood of winning based on probability, not as they might play the hand in a real poker game (e.g., by bluffing). Participants were first asked to estimate the probability of winning ("What is the probability of winning this hand?") by choosing one of 10 probability intervals (0–10%, 11–20%, 21–30%, 31–40%, 41–50%, 51–60%, 61–70%, 71–80%, 81–90%, and 91–100%). Next, participants were asked to decide whether they wanted to play the hand or not ("Do you want to play this hand?"). After deciding to play or fold the hand, the next hand was presented, participants were asked to estimate the probability, and so forth.

The task consisted of 50 trials with no feedback between trials. The probability of outcome was calculated for each hand with a computer program simulating 10 million gambles. The task involved no betting, and did not include turn or river cards.

### Estimation bias, decision bias, and cognitive bias model

*Estimation bias* was defined as the difference between estimated probability and true winning probability:

$$\text{Estimation bias} = (EP - P) \quad (1)$$

where EP is the estimated probability of winning and P is the probability of winning. We also calculated the *absolute* estimation bias, as the deviation of estimated probability (positive or negative) from the true probability, to determine the total degree of estimation bias:

$$\text{Absolute estimation bias} = \sqrt{(EP - P)^2} \quad (2)$$

where the square root of the product of EP – P expresses the absolute deviation of estimated probability from the true probability.

*Figure 1.* The poker task simulates a real-life on-line poker task in which the participant has to estimate the probability of outcome and choose to accept or reject gambles. The task uses a Texas Hold'em setup, with one opponent indicated by cards face down at the top of the figure. The player's pocket cards are shown at the bottom of the figure, with the shared cards (the flop) in the middle. The opponent's pocket cards (face down) are shown at the top. No feedback is provided in the task. After each gamble (hand), the task continues to the next hand.



From the probability estimates, four types of decisions and two types of *decision bias* can be made on the poker task: (1) *incurred losses*, that is, acceptance of low probability gambles ( $p < .5$ ); (2) *foregone gains*, that is, rejection of high probability gambles ( $p \geq .5$ ); (3) *avoided losses*, that is, rejection of low probability gambles; and (4) *gains*, that is, acceptance of high probability gambles. The first two decisions are disadvantageous decisions because they lead to losses or missed gains over time; the latter two are advantageous decisions because they lead to avoided losses or gains over time. The overall *skill* level was calculated as the number of advantageous minus disadvantageous decisions:

$$\text{Skill} = (\text{AL} + \text{G}) - (\text{IL} + \text{FG}) \quad (3)$$

where AL is avoided losses, G is gains, IL is incurred losses, and FG is foregone gains. Incurred losses and avoided losses are two different ways of expressing decision making in relation to loss behavior, whereas gains and foregone gains are two different ways of expressing decision making in relation to winning behavior. Therefore, one or the other set of measures can be used to calculate decision bias in relation to estimation bias. We used estimation bias ( $EP - P$ ), incurred losses, and foregone gains to determine the probability that an individual belonged either to the experienced or to the inexperienced

Table 1  
Decision bias and estimation bias between experienced and inexperienced poker players

	Experienced players (n = 5)		Inexperienced players (n = 4)		F
	Mean	SD	Mean	SD	
	Absolute estimation bias $\sqrt{(EP - P)^2}$				
All gambles	0.091	0.011	0.136	0.032	9.09**
Accepted gambles	0.087	0.008	0.135	0.035	9.06**
Rejected gambles	0.094	0.022	0.111	0.075	0.22
	Estimation bias (EP - P)				
All gambles	0.024	0.035	-0.064	0.093	3.88*
Accepted gambles	0.066	0.015	-0.065	0.095	9.49**
Rejected gambles	-0.023	0.068	-0.052	0.107	0.25
	Decision bias				
Skill	31.20	2.280	17.00	17.166	3.47*
Avoided losses	20.60	1.517	13.00	10.424	2.68
Losses	7.40	1.517	15.00	10.424	2.68
Gains	20.00	1.732	20.50	2.380	0.13
Foregone gains	2.00	1.732	1.50	2.380	0.13

Note. EP = estimated probability of winning; P = probability of winning.  
\* $p \leq .05$ , one-tailed. \*\* $p \leq .025$ , two-tailed.

group. Mathematically, the model was expressed as follows:

$$P(G|EB, IL, FG) = \frac{1}{1 + \exp \{ -(\alpha_1 EB + \alpha_2 IL + \alpha_3 FG) \}} \tag{4}$$

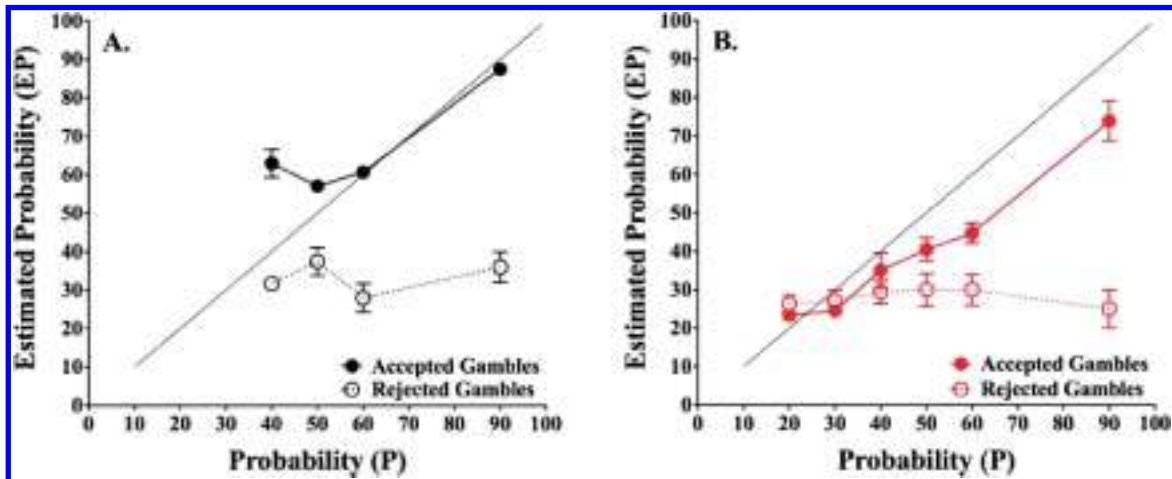
where G represents group and EB, IL, and FG denote estimation bias, incurred losses, and foregone gains. The coefficients (alpha 1, 2, and 3) were estimated from the experiment.

Table 1 shows that EPPs had significantly smaller absolute estimation bias ( $\sqrt{(EP - P)^2}$ ) than did IPPs,  $F(1, 7) = 9.09, p < .025$ . This finding suggests that EPPs had more accurate probability estimation than did IPPs. EPPs also had significantly smaller absolute estimation bias in accepted gambles,  $F(1, 7) = 9.06, p < .025$ , whereas no differences were found in rejected gambles.

EPPs differed significantly from IPPs in estimation bias (EP - P),  $F(1, 7) = 3.88, p < .05$  (one-tailed). On average, EPPs overestimated the probability of winning by 2.4%, whereas IPPs underestimated the winning probability by -6.4%. The largest differences were found in accepted gambles,  $F(1, 7) = 9.49, p < .025$ , where EPPs overestimated the winning probability by 6.6% and IPPs underestimated the probability by -6.5%. We found no differences in estimation bias of rejected gambles. For within group differences in estimation bias, EPPs significantly overestimated accepted gambles relative to rejected gambles,  $F(1, 8) = 8.13, p < .025$ , whereas IPPs did not differ in estimation bias between



Figure 2. Estimated probability of accepted and rejected gambles across probability intervals. (A) Experienced poker players estimate the probability of winning as significantly higher for accepted gambles (filled circles) than for rejected gambles (open circles). Only intervals with both accepted and rejected gambles are included. (B) Inexperienced poker players do not differ in estimated probability between accepted gambles (filled circles) and rejected gambles (open circles), except for the 90% to 100% probability interval.



accepted and rejected gambles. A comparison of estimation bias across probability intervals (Figure 2A) showed that EPPs had the largest overestimation of gambles in the 41% to 60% interval, whereas IPPs underestimated probabilities throughout the probability intervals, with the exception of very low probabilities (Figure 2B).

For decision bias, EPPs had a significant higher skill level than did IPPs. The differences, however, reached only a one-tailed significance level,  $F(1, 7) = 3.88, p < .05$ . EPPs and IPPs did not differ in the number of choices resulting in incurred losses or gains or in avoided losses or foregone gains.

A correlation analysis between estimation bias and decision bias showed significant correlations between skill level and estimation bias,  $r(9) = 0.67, p = .05$  (one-tailed), and absolute estimation bias,  $r(9) = -0.78, p < .025$ . The results are illustrated in Figure 3. Absolute estimation bias was also significantly correlated with avoided losses,  $r(9) = -0.73, p < .05$ , and incurred losses,  $r(9) = 0.73, p < .05$ . The correlation analysis is summarized in Table 2.

Finally, we determined the ability of estimation bias and decision bias to correctly classify players as EPPs or IPPs. We used estimation bias, incurred losses, and foregone gains as predictive variables. We assigned probability weights to each of the measures and summed them in a combined cognitive bias probability weight (see Figure 4). On the basis of these cognitive bias weights, we tested whether we could identify EPPs and IPPs from their cognitive biases. Figure 4A shows that estimation bias accurately classified seven of nine players. Any arbitrary horizontal line would mistakenly classify at least two players as

Table 2  
*Correlations between estimation bias and decision bias*

	Skill	Avoided losses	Incurred losses	Gains	Foregone gains
Absolute estimation bias $\sqrt{(EP - P)^2}$	-0.78***	-0.73**	0.73**	0.24	-0.24
Estimation bias (EP - P)	0.67*	0.55	-0.55	0.08	-0.08

*Note.* EP = estimated probability of winning; P = probability of winning.

\* $p \leq .05$ , one-tailed. \*\* $p \leq .05$ , two-tailed. \*\*\* $p \leq .025$ , two-tailed.

EPPs or IPPs. Similarly, incurred losses (Figure 4B) and foregone gains (see Figure 4C) each classified seven of nine participants accurately as either EPPs or IPPs. Each of these measures, however, accurately classified different individuals such that the combined model accurately classified all nine individuals as either EPPs or IPPs. Figure 4D shows the total model with a horizontal dashed line indicating the discrimination level between experienced and inexperienced players.

## Discussion

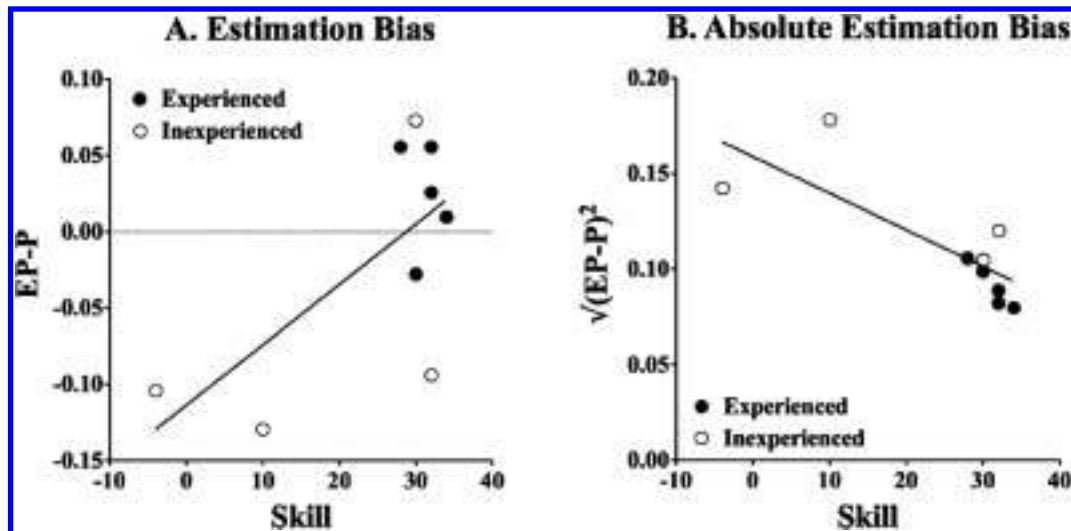
In this study, EPPs had significantly lower estimation bias and decision bias than did IPPs, and EPPs showed significant differences in estimation bias of accepted and rejected gambles. EPPs overestimated accepted gambles predominantly in the 41% to 60% winning probability range. It was possible to accurately classify all players as EPPs or IPPs from statistical modeling of their estimation bias and decision bias.

EPPs had significantly lower absolute estimation bias and significantly higher skill level, although the latter reached only a one-tailed significance level. The data show that the poker task can accurately differentiate estimation bias and decision bias in EPPs and IPPs, and further research should therefore replicate our results in a larger sample size. In particular, a larger sample size is needed to reliably determine the tasks' ability to detect differences in skill level between EPPs and IPPs.

Although EPPs significantly differed in estimation bias between accepted and rejected gambles, we found no differences in IPPs. This finding suggests a poorer integration between estimation and choice in IPPs and may indicate that estimation bias and decision bias are independent or partly independent variables. The correlation between estimation bias and skill level is consistent with this notion: As the absolute estimation bias decreased, the skill level increased. This observation suggests that more accurate estimation is associated with better performance and that the convergence of estimation and skill level is higher in EPPs. The correlation between absolute estimation bias and skill level suggests a learning effect in EPPs.



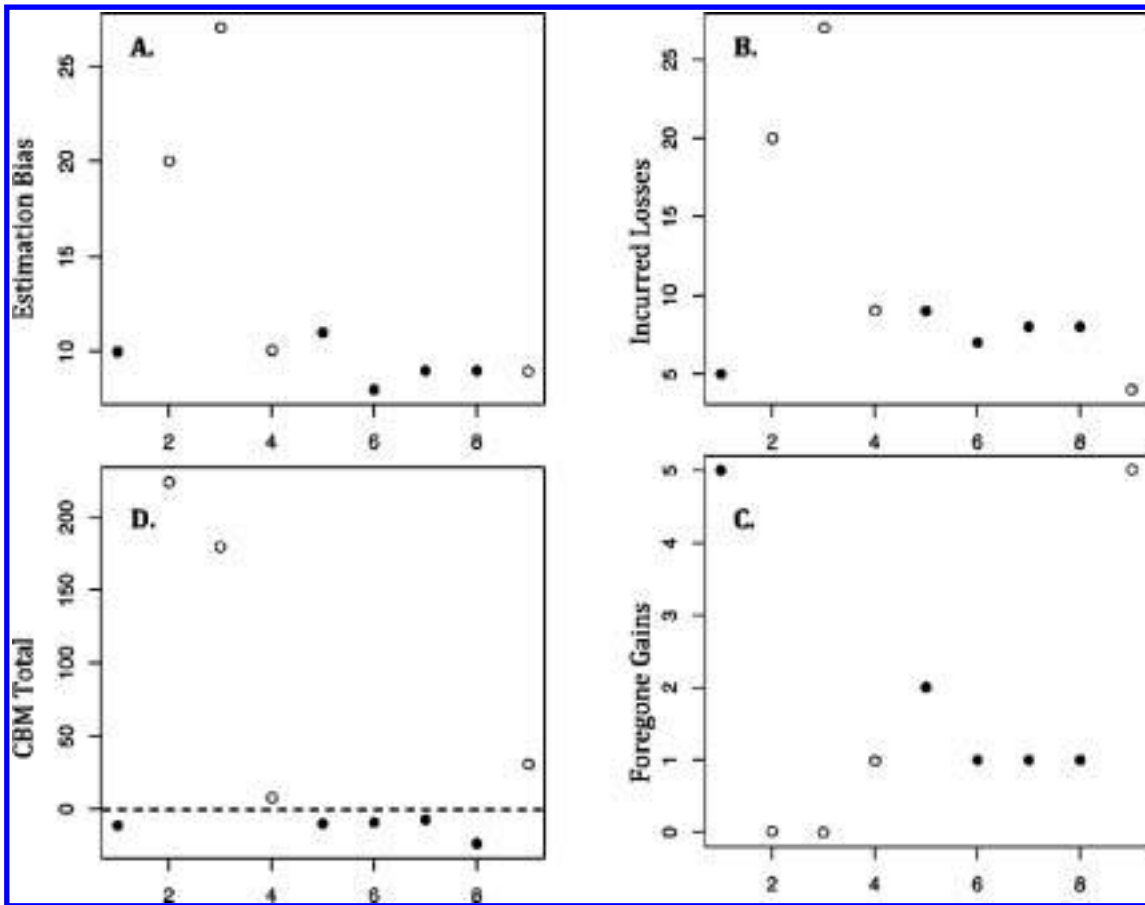
Figure 3. Correlation between skill and estimation bias and absolute estimation bias. (A) Estimation bias ( $EP - P$ ) and skill level are significantly correlated,  $r(9) = 0.67$ ,  $p = .05$  (one-tailed). Experienced poker players are indicated with filled circles and inexperienced poker players are indicated with open circles. The line indicates the regression slope for the whole group. (B) Absolute estimation bias ( $\sqrt{(EP - P)^2}$ ) and skill level are significantly correlated,  $r(9) = -0.78$ ,  $p < .025$ .



Our data may have implications for pathological gambling in two ways: Pathological gamblers may have either (1) impaired estimation bias that contributes to impairments in skill level; or (2) intact estimation bias, but a poorer integration between estimation bias and decision bias, leading to poorer choices despite accurate estimation. An interaction of both variables, of course, is also possible. Further studies are needed to determine whether pathological gamblers have impaired estimation bias, impaired decision bias, or a combination of both. If pathological gamblers have these impairments, their performance level could fall between that of IPPs and EPPs. Over time, such a behavioral pattern will lead to losses against experienced poker players with better skill level. Uncorrected cognitive biases might lead to continued gambling despite losses, known as “chasing one’s losses” (Dickerson, Hinchy, & Fabre, 1987; American Psychiatric Association, 1994; Linnet et al., 2006; O’Connor & Dickerson, 2003).

EPPs significantly overestimated the winning probability compared with IPPs, especially with regard to accepted gambles; they predominantly overestimated gambles in the 41% to 60% winning probability range. EPPs may have overestimated mid-range probabilities for several reasons. First, they may have had less experience with playing hands in the 41% to 60% probability range, thus leading to a larger estimation bias in this range. Second, EPPs may have successfully played these hands in the past and won either by having opponents fold or by winning the hand despite lower odds. This could reinforce an estimation bias on that particular hand or on hands similar to it. Third, EPPs may have attributed value rather than probability to some of the low probability hands. Most EPPs will alternate between playing weaker hands and stronger hands to prevent appearing too predictable. Some hands

Figure 4. Differentiation between experienced and inexperienced poker players on the cognitive bias model. Experienced and inexperienced poker players are differentiated on the basis of (A) estimation bias, (B) incurred losses, and (C) foregone gains. Each variable accurately classifies seven of nine participants as either experienced (closed circles) or inexperienced (open circles) poker players. Different individuals are accurately classified by the three variables. The combination of variables in the cognitive bias model (CBM) (D) shows perfect discrimination, with inexperienced poker players all scoring above threshold (dashed line) and experienced poker players all scoring below threshold. Numbers on the abscissa refer to participants, whereas numbers on the ordinate refer to probability weights of the individual variables.



may therefore have a higher value to EPPs even though the winning probability of the hand is lower. This explanation would particularly make sense in the 41% to 50% range, which is where we saw the largest overestimation of experienced players. Although there was nothing to suggest problem or pathological gambling behavior in our EPPs, the mid-range probabilities may constitute a probability spectrum in which pathological gamblers are particularly at risk for overestimation or overinclusion of low-probability hands.

EPPs and IPPs did not differ in estimation bias on rejected gambles. On the one hand, this finding may suggest that neither group had much experience with these hands because

unplayed hands hold little information. On the other hand, it may suggest that EPPs do not pay much attention to long-shot gambles. Knowing whether a hand has a 24% or 34% chance of winning is not as useful as knowing whether it has a 64% or 74% chance of winning.

All players were accurately classified as EPPs or IPPs from statistical modeling of estimation bias, incurred losses, and foregone gains. This finding supports the validity of the poker task and may have implications for the study of cognitive biases in problem and pathological gambling. Problem and pathological gamblers are known to take larger risks and to be overconfident in their decision making (Goodie, 2003, 2005; Lakey et al., 2006, 2007). It is therefore possible that the poker task could differentiate between EPPs and pathological gambling poker players. However, further studies are needed to support this hypothesis.

Our study holds several limitations, which warrants replication by independent research. First, the study needs to be replicated in a problem gambling cohort to test the hypothesis that cognitive biases impair problem and pathological gamblers. Second, the study needs to be replicated with a larger sample size. Third, including ratings of confidence levels could provide important information about the role of confidence in relation to estimation bias and decision bias. Fourth, although we found a clear interaction between estimation bias and decision bias, our study could not determine the causality of factors, that is, whether overestimation led to acceptance of gambles, or whether accepted gambles were overestimated. Fifth, the poker task addresses only a limited number of poker-related variables (i.e., probability estimation and choice). Poker is a very complex game, which heavily involves social interaction (e.g., in betting and bluffing). The poker task in this study did not address these variables and cannot determine the degree to which they might have been present in the cognitive biases examined here. Finally, we note that all EPPs were male and all IPPs were female. Although we found significant differences between EPPs and IPPs, we cannot exclude the possibility that gender influenced some of these differences. Consequently, our findings should be reproduced in a sample that controls for gender differences.

In conclusion, this study showed that EPPs have significantly lower estimation bias and decision bias than do IPPs. Despite having significantly higher overestimation, EPPs make better decisions than IPPs. Additional research is necessary to determine whether these differences hold implications for the study of cognitive biases in pathological gambling and addiction.

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